# Quantum Cascade Lasers: Temperature Performance and Surface Cooling

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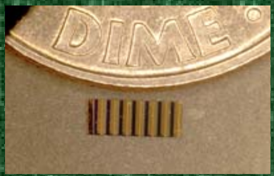
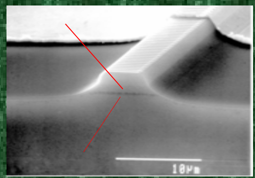
## What are Quantum Cascade Lasers? 1

They are semiconductor injection devices that emit light in the mid and far infrared portion of the spectrum.



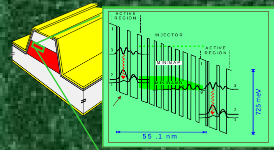

## Applications 2

- Trace gas sensing e.g CO, NO, COS …etc
- Free space optical wireless communication
- Infrared counter-measures

- Metal detection (Terahertz)
- Astronomical applications (Terahertz)
- ….etc

## Temperature problem of Quantum Cascade Lasers 3

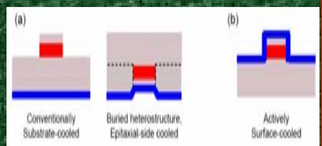
- The core of active regions and injectors heats up enormously.
  - Less than ~10 % of the electrical power is converted to optical power
  - High duty cycle or continuous wave operation is limited
  - High threshold currents.
  - Reduced optical power



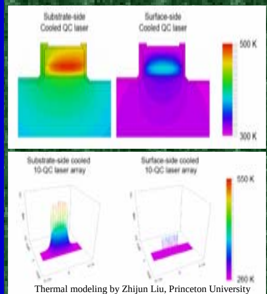

## Temperature Performance of QC Lasers was studied using two methods of cooling 4

a) Cooling by conduction through substrate (traditional method).

b) Active surface cooling using liquid nitrogen.




## Thermal modeling 5

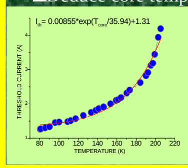


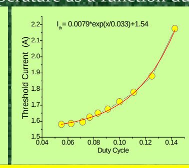

Thermal modeling by Zhijun Liu, Princeton University

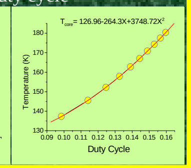
- When cooled by conduction, core temperature reaches 500K before continuous wave operation terminates.
- When cooled actively, core temperature reaches only 380K; therefore, continuous wave operation is still possible.

## To determine the QC laser core temperature characteristics 6

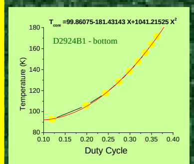
- Measure threshold current versus heat - sink temperature at low duty cycles
- Measure threshold current versus duty cycle
- Deduce core temperature as a function duty cycle

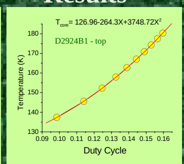


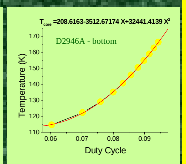




## Results 7

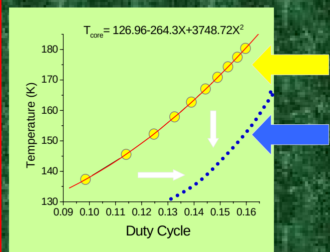



- Graph shows behavior of core temperature as a function of duty cycle for bottom-D2924B1, top-D2924B1 and bottom-D2946A when cooled by conduction into substrate.

## Outlook 8




**Measured data: Cooling by conduction through substrate**

**Expected performance: Cooling through surface significantly reduces core temperature**

## Conclusion 9

Thermal modeling predicts that surface cooled lasers will behave better than substrate cooled lasers. Substrate cooled lasers have been characterized and core temperature has been determined. Future work will determine the core temperature of surface cooled lasers.

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